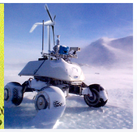



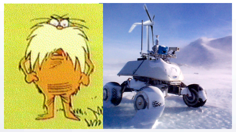
LORAX

Life on Ice Robotic Antarctic Explorer

PI: Liam Pedersen, NASA Ames

(presented by C. McKay and D. Wettergreen)

A robotic traverse across the Antarctic continent to assess the microbial biogeography of the polar plateau and determine the sources and sinks of microorganisms on the ice.



Overview

Introduction

Science

- Goals
- Antarctic locations
- UV spectroscopy

Technology Goals and Challenges

FY 03 reality & plan

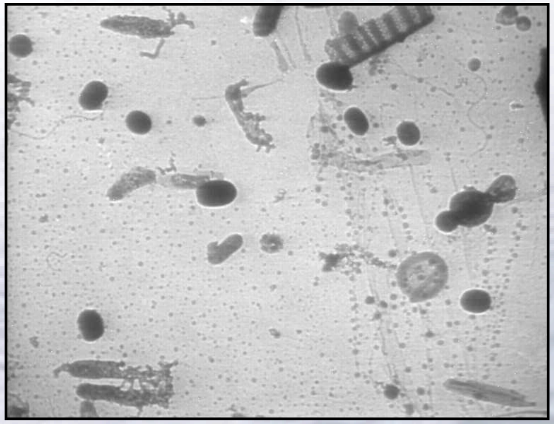
- Field deployable UV spectrometer and sample acquisition device
- Nomad rover
- Rover + autonomy study

Long term goals

LORAX Mission Concept

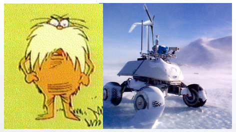
“Bio-geographical” map of Antarctica

- Small to large scale
- Traverse diversity of environmental conditions
- UV spectrometer to detect auto-fluorescence of microbes

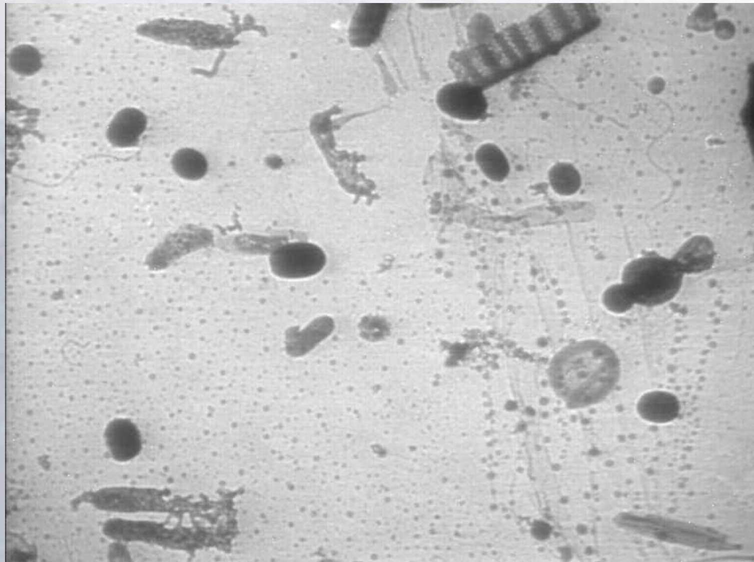


Antarctic Rover

- Long distance, unsupported traverse
- Non-contaminating
- Automated sample acquisition



Science Mission: Astrobiology Survey of Antarctic Ice



Goals:

Seek limits of life in Polar Environment

Understand habitat

Microbes known to exist in polar ice [Carpenter et al]:

- Marine diatoms, terrestrial microbes

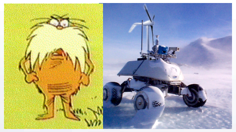
Geographical distribution and habitats not yet studied.

Transport and preservation mechanism not studied.

Antarctica is planetary analog

- Antarctic min and Mars max temperatures overlap

Applicable to Mars polar ice cap



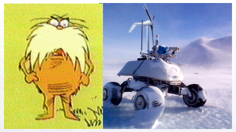
Science Hypotheses

H1: The concentration of micro-organisms on the surface (1 cm) of the polar plateau will be between 100 to 10,000 cells/g of ice.

H2. The distribution of micro-organisms on the surface of the polar plateau will vary considerable in relation to the distance, wind direction and ice-flow direction to sources of bacteria. These sources include the marine environments, isolated nunataks, and dry valleys.

H3. There will be significant differences in micro-organisms concentrations between locations on the polar plateau of accumulation (firn), flow (pack hard snow), and sublimation (blue ice).

H4. There will be significant differences between the diversity and amount of micro-organisms at the surface of the polar firn and in the snow several centimeters below the surface, due to the selection effect of dry condition and the UV flux at the surface.



Required Science Measurements

Multiple geographic scales

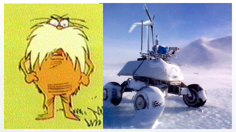
- 5 km across glacier
- 30km around Nunatak
- >100km from ice shelf to polar plateau (along glacier)
- [>1000km trans-continental]

100 data-points / traverse

At each sample point determine:

- # microbes / gram ice (all kinds)
- viable:non-viable microbial ratio
- Chlorophyll : Non-Chlorophyll bearing microbial ratio

NO robotic microbial identification or microscopic imaging
(part of ground truth studies)

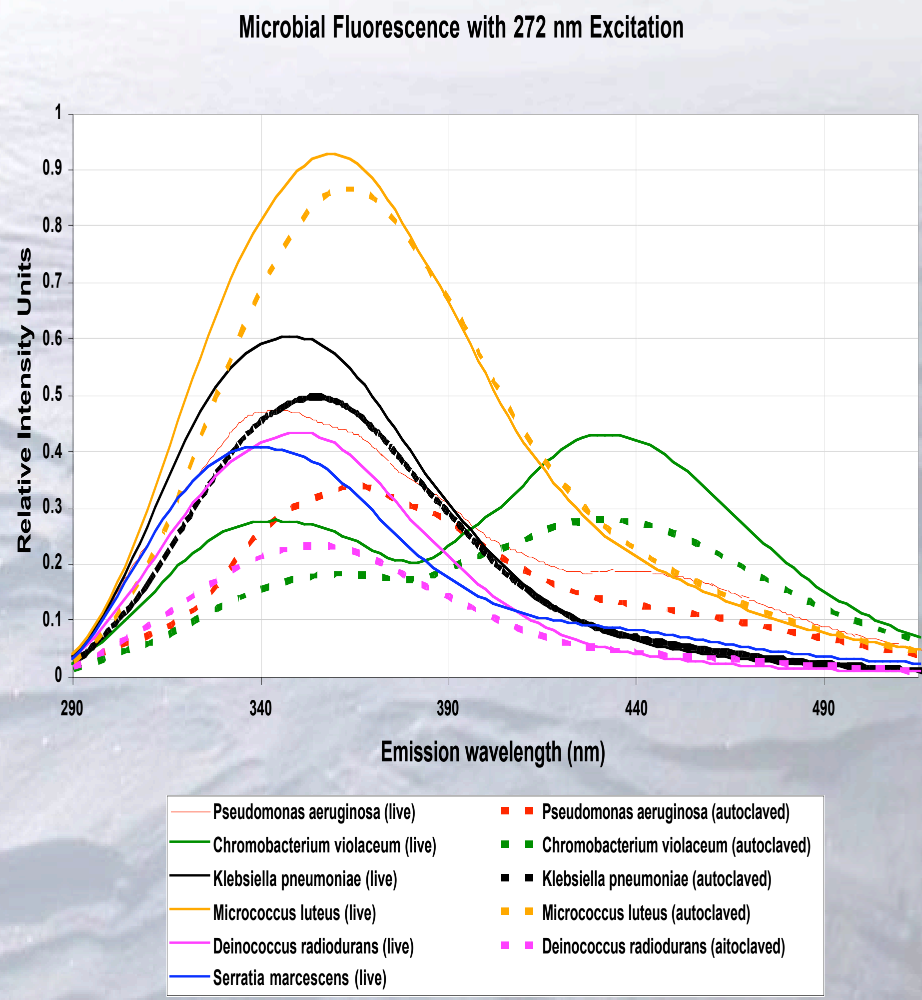


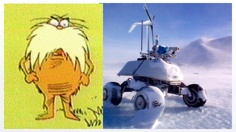
UV spectroscopy for Detection and Characterization of Life

- Biomolecules fluoresce when illuminated by UV light (table)
- Characteristic excitation and emission wavelengths
- Discriminate between various bio-molecules and minerals
- Robust to changes (ie death) in microbes

Some common fluorescent biomolecules

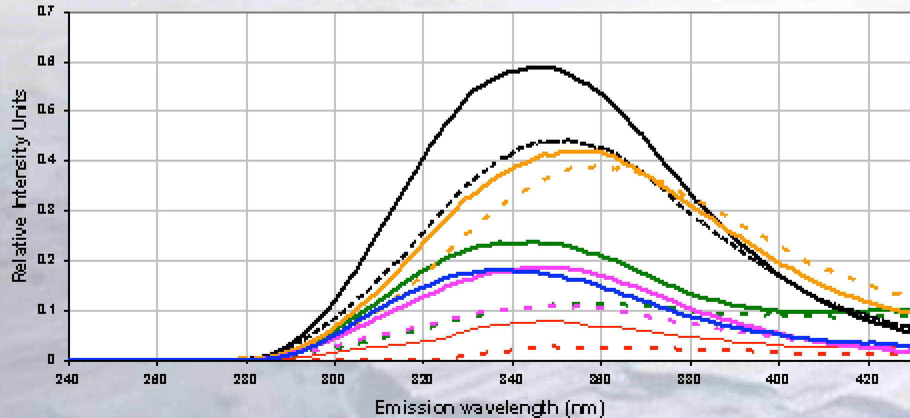
Compound	Peak Excitation Wavelength (nm)	Peak Emission Wavelength (nm)
Tryptophan	~ 270, 230	335
NADH	~360	~450
F_{420}	420	~470
Chlorophyll-a	> 360	685
Flavins	~460	~540
PAHs	~300	~450



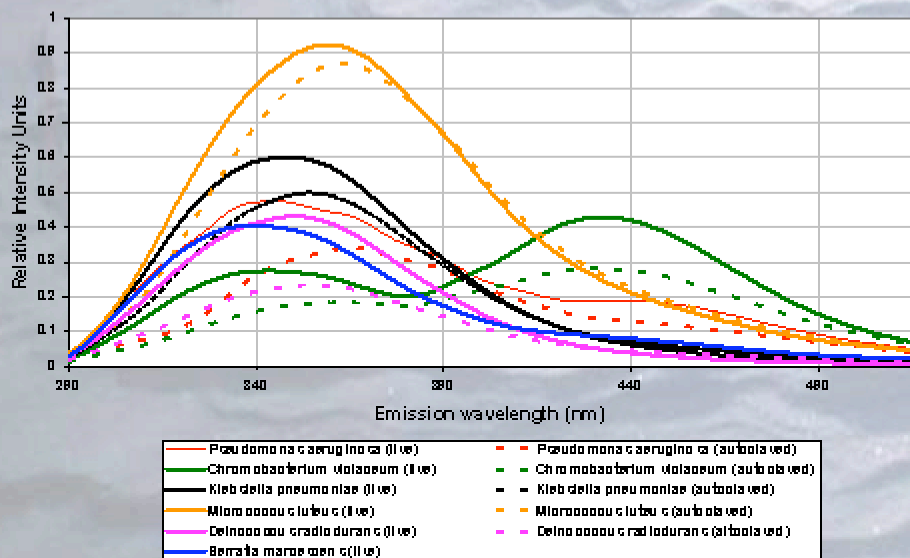


Effect of Soil Contamination

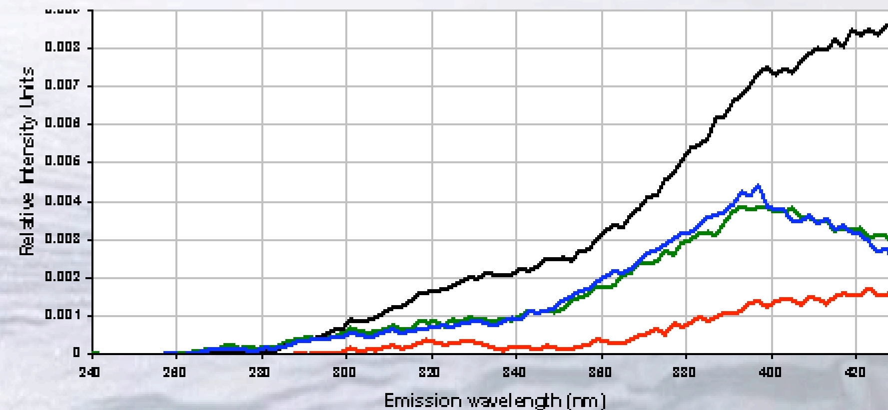
Microbial Fluorescence



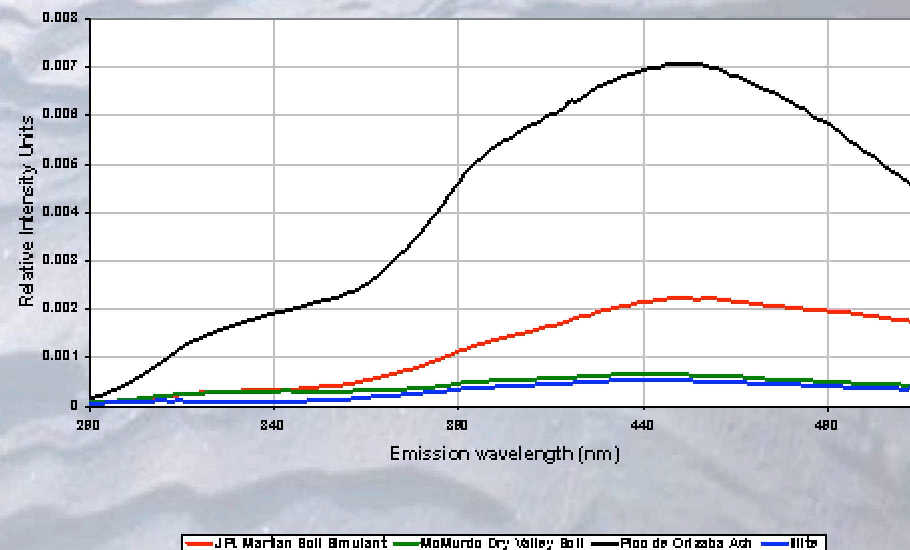
Microbial Fluorescence with 272 nm Excitation



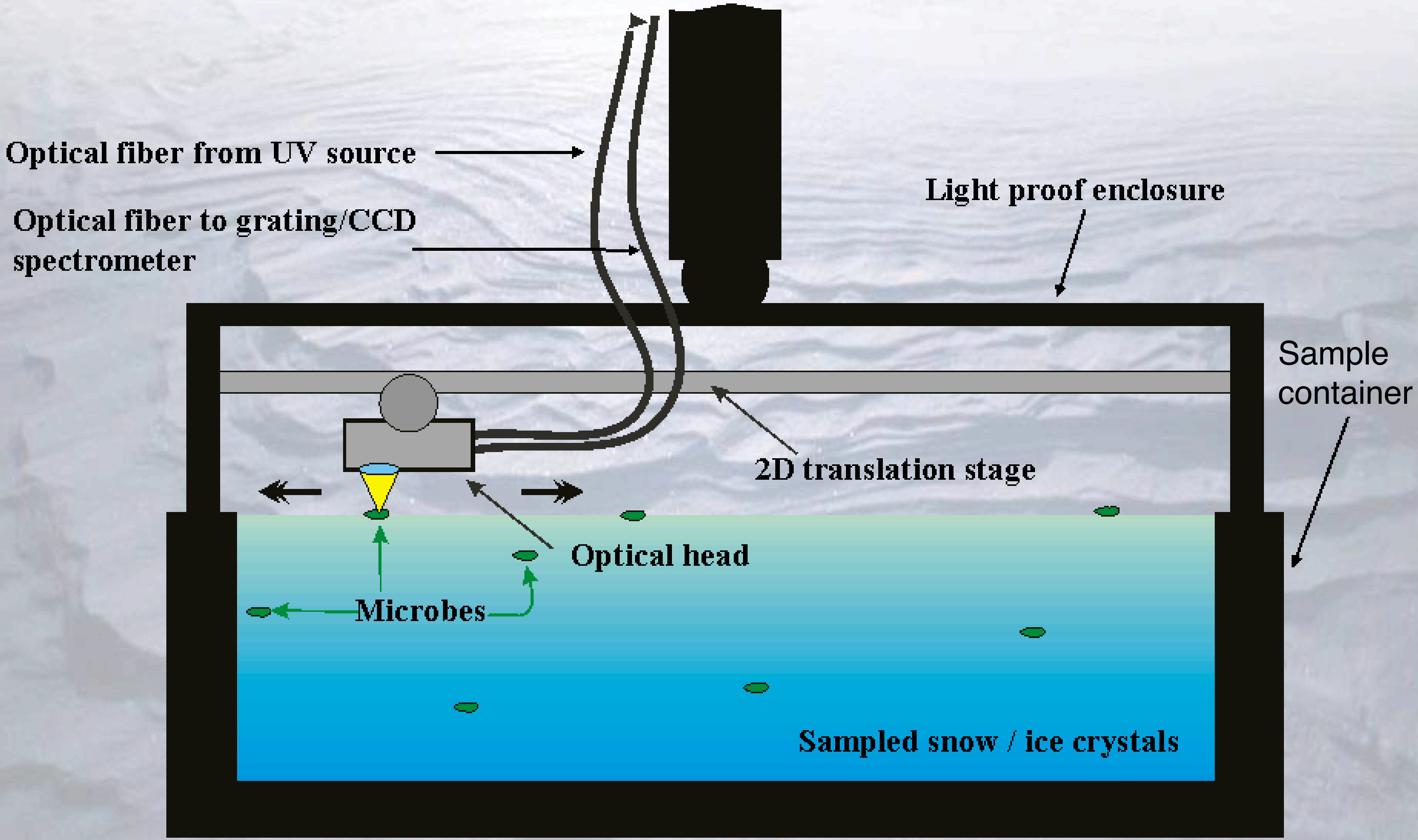
Mineral Fluorescence (~ x100 mag)



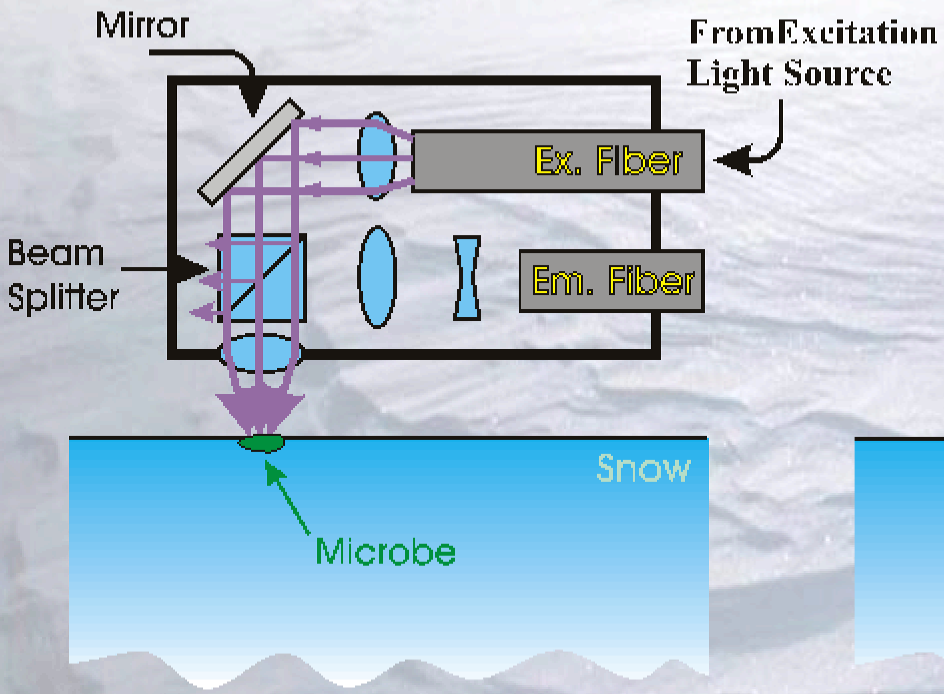
Mineral Fluorescence with 272 nm Excitation



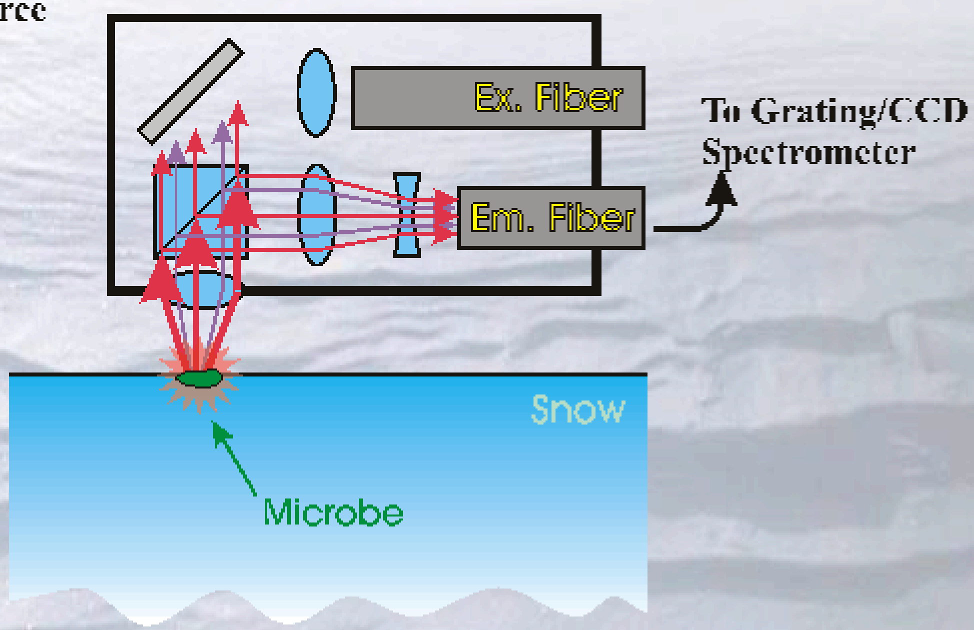
UV Fluorescence Instrument



UV Sensor Head



Exciting Fluorescence



Collecting Fluorescence

Sample Acquisition and Handling

Ice crystals brought to light-tight enclosure for UV measurements

Retrieve ice samples just below surface:

- Less contamination
- Less UV

Nomad arm lowers sampler onto ice/snow

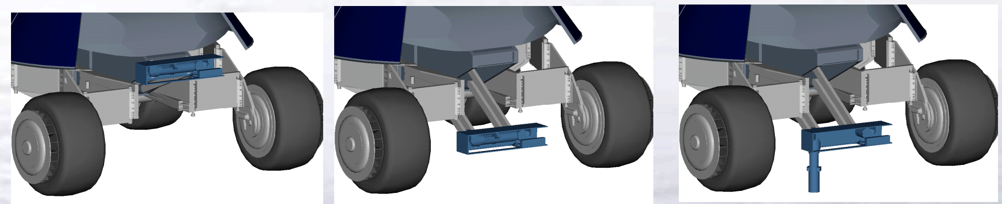
Sampling mechanism fills sample plate with ice crystals.

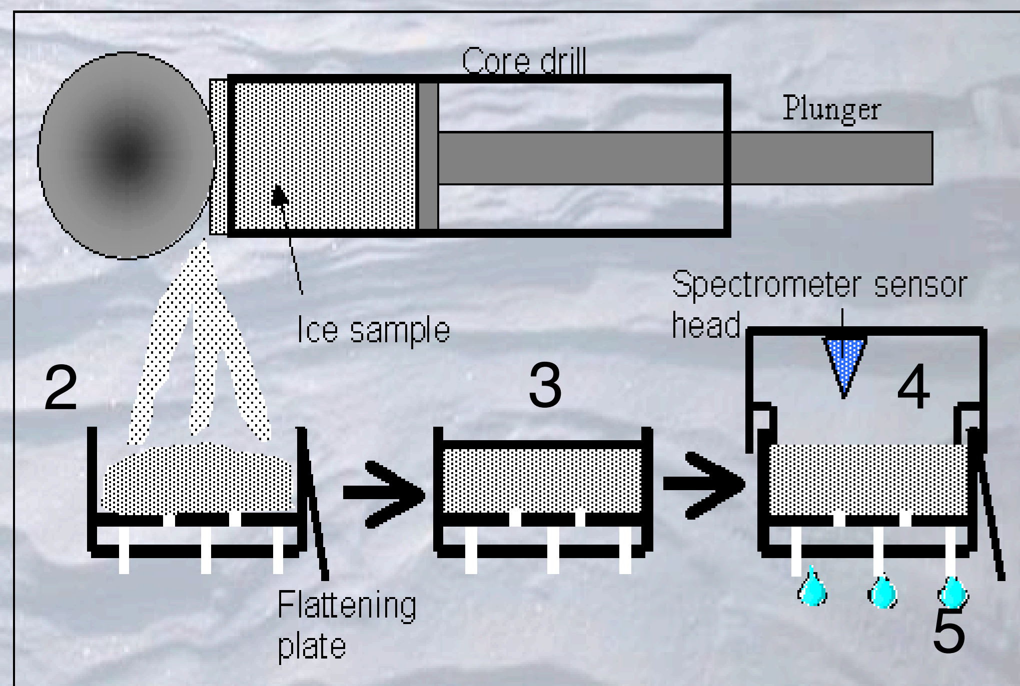
Samples flattened

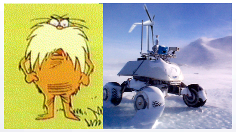
UV instrument + light tight enclosure brought onto sample plate.

Discard sample ice crystals

- Melt, and let drain away
- Decontaminate







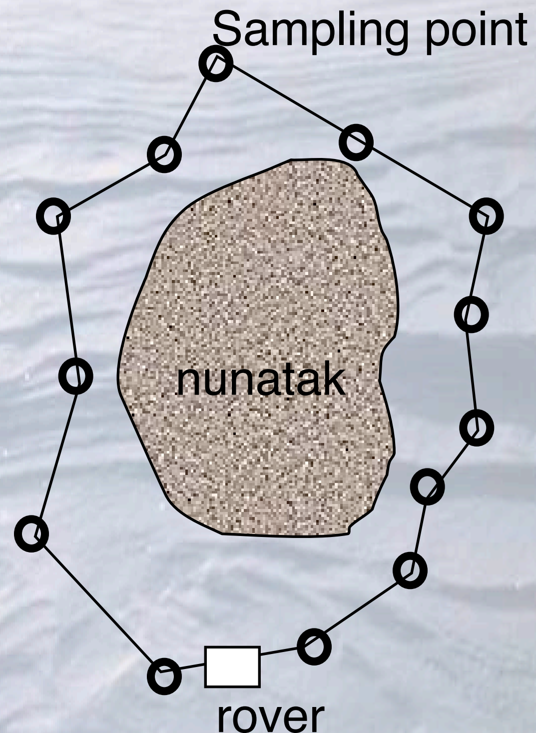
Circumnavigation of a Nunatak

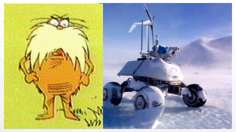
Are nunataks sources?

Wind transport?
- concentration downwind

Ice flow transport?
- concentration follows ice

Small scale example of the same science questions to be addressed on the scale of the continent.





Planetary Relevance

Mars Polar Layer Deposits (2011 POL mission)

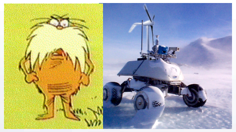
- Long traverse on ice
- Repeated surface sampling, shallow coring

Lunar Polar Search for Water Ice

- Repeated surface sampling, shallow coring

Europa Surface Exploration

- Long traverse on ice



Technology Goals and Challenges

Field detection of Microbes in Ice

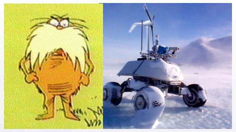
- Antarctic Robot deployable instrument
- Planetary relevant design
- Avoid consumables

Sample acquisition and handling

- Field robust mechanism, planetary relevant design
- Access snow/ice up to 10cm below surface
- Mitigate cross contamination

Polar Mobility & Power

- 100km+ distance capability in 30 days
- 5-day unattended rover operations
    - Limited communication cycle
    - Navigation autonomy in polar environs
    - Tactical autonomy for power management and fault recovery
- No contamination near sampling points (no a priori access)



Nomad

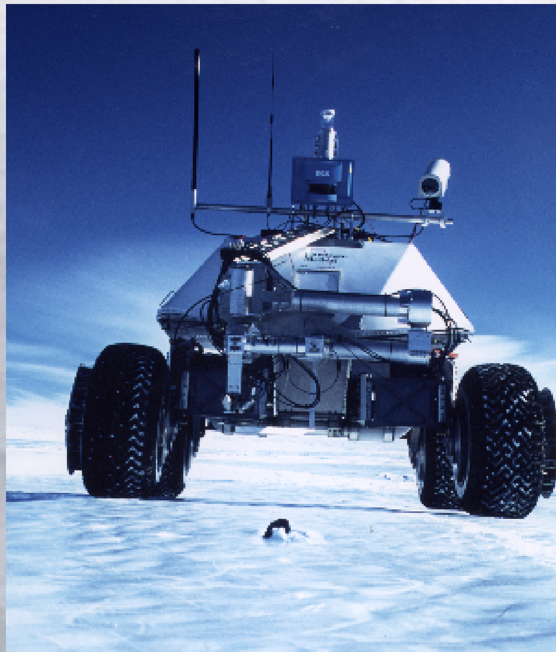
Atacama Desert Trek 1997

- Demonstration of long-distance traverse
- 220 kms of travel on the Llano de la Paciencia near Salar de Atacama
- Teleoperation and limited autonomy (with Morphin)

Nomad in Chile

Fossilized stromatolite detected remotely

Nomad



Antarctic Meteorite Search 1999 & 2000

Automatic detection and classification of rocks on stranding surfaces in the Antarctic where meteorites tend to concentrate

Nomad

Development to enable long-distance autonomous navigation

- Upgrade avionics
- Port Hyperion navigation software
- Enhance terrain perception capability
- Reduce mass and power use
 to improve endurance
- New power system

  Sustainable

  Non-contaminating

Nomad Today

Terrain Conditions and Hazards

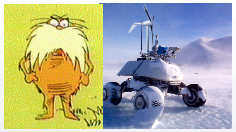
Soft snow

Sastrugi

Blue Ice

Grades

~~Crevasses~~



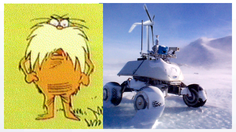
Polar Navigation

Polar Perception

- Laser reflected off ice
- Vision blinded by snow (blown and lack of texture)

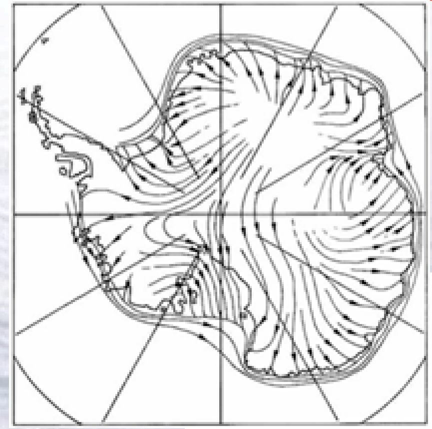
Polar Terrain Navigation

- Localization is difficult without global reference (GPS) but accuracy may not be tight constraint
- Obstacles typically topological rather than discrete

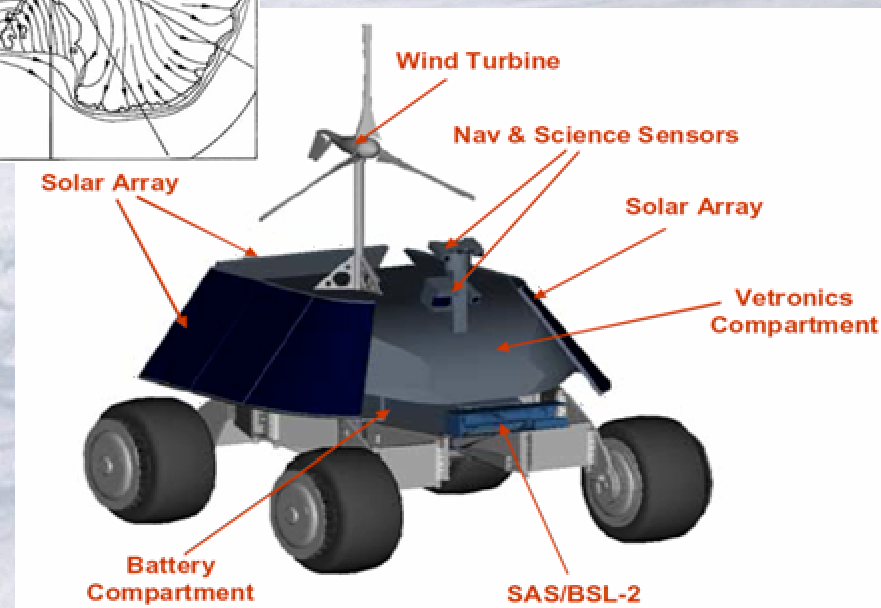


Sustaining Power

Wind
- Katabatic wind, steady 30 knots
- Variable output ($1.5m^2$):
- 100 W at 15 knots
- 400 W at 30 knots
- Swept volume complicates design
- Vulnerable to wind forces and icing

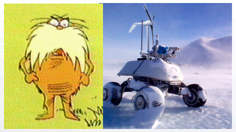


Solar
- Relatively vertical, not horizontal, array
- $100W/m^2$ (Si)
- Diminished by atmosphere and weather



Battery
- Secondary storage for low production (low wind) and/or

Other Sources:
Fuel Cells **High energy density**
Negligible contamination
Longevity
Space relevant



LORAX Investigation Concept

Objectives:

Time < 30 days

- Plan for 50% poor weather

Must complete fixed distance:

- 40km nunatak circumnavigation
- 100km Taylor valley traverse

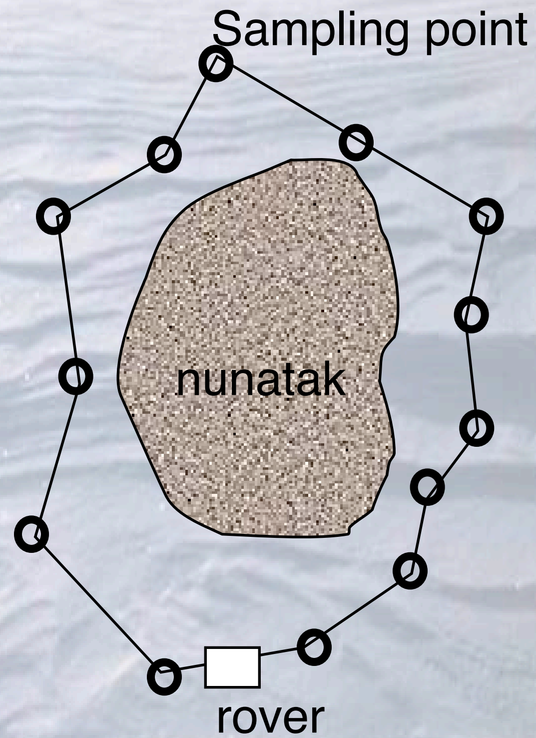
At least 100 measurements

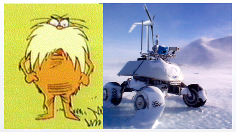
Mars-like operations

- Limitation on comm opportunities
- Bandwidth restrictions

Uncertainties:

- Weather
- Power production and use
- System performance
- Optimal science locations





LORAX Activities

Fluorescence Instrument

- Obtain source and spectrometer for field prototype

Sample Acquisition

- Detail mechanical design
- Build prototype to test decontamination

Rover (Nomad)

- Mechanical checkout
- Power repair/upgrade
- Avionics rebuild/upgrade
- New navigation sensing (laser) and range (far-field)
- Port and tune Hyperion navigation software
- Re-architect for reuse and CLARAty

System design and architecture

- Instrument accommodation
- Power system
- Thermal system
- Autonomy system
- Rover configuration and mobility
- Rover interface (science and engineering)

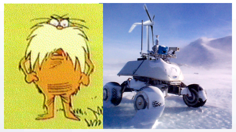
Experimentation and data collection

- Polar terrain (sastrugi, open crevasses), review existing data
- Wind powet
- Antarctic borehole fluorescence sensor
- Decontamination of SAD with tracers

Science and Technology Plan

- Ground truth and instrument validation
- Concept of operations

Extra Material



Precursor to Future Mission Concept

<u>Science-driven Technology Demonstration Program:</u>

3000 km Trans-Antarctic Unattended, Autonomous Robotic Traverse

NASA Mission Approach:

- Science Definition Team (SDT)
- Openly competed elements

Relevant Science:

- Limits of Life
- Understand Global Climate

Up-front Technology Investment for Reduced Operations Cost:

- Mobility & Power
- Autonomy & Reliability